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A HUMIDIFIER FOR LEMON CURING ROOMS.

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INTRODUCTION.

In the summer of 1914 the writer became interested in some studies having for their object the control of humidity in the curing rooms of one of the lemon packing houses in southern California. These rooms, 20 in number, are about 20 feet long by 20 feet wide and 10 feet high. They are arranged five on each side of two corridors, which are covered by monitor-type ventilators with slatted sides. The rooms are equipped with ventilating doors along the outer bottom side and inner top side, arranged in such a way that they can be opened easily and held in any position desired, or can be closed so as to prevent any appreciable movement of air from the rooms.

The walls of the rooms are made of galvanized steel. A 4-inch space between the walls, on all sides of the room except the bottom, is filled with redwood sawdust. The floors of the rooms are made of 2 by 4 inch wooden stringers laid flatwise on the joists, with half-inch spaces between them. Underneath each room is a small earth cellar, or pit, in which to place heating appliances for use in raising the temperature of the rooms.

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The condition of relative humidity in the curing rooms is determined by the use of a sling psychrometer. Distilled water at the room temperature and clean cloth covers for the wet bulb have been used, and the directions recommended by the United States Weather Bureau for making accurate use of the sling psychrometer have been carefully followed.

Studies were made to determine the humidity of various parts of empty and filled rooms under different conditions of ventilation, in order to establish intelligently a practicable and satisfactory method for making regular humidity observations. Preliminary determinations of the humidity outside the curing rooms and inside under different conditions of ventilation were made before any control measures were attempted. Regular hourly tests of the relative humidity were made with the sling psychrometer in several parts of the room. In addition to these observations a hygrothermograph was placed in each room, in order to keep a continuous record of the conditions of temperature and humidity.

OBJECT OF THE EXPERIMENTS.

The object of the humidity studies was to determine the effect of various percentages of relative humidity in the curing rooms upon the curing processes of the lemons and to find out, if possible, the condition resulting in the most satisfactory curing, as shown by the color and texture of rind, the amount of shrinkage during storage, the color and condition of the calyx, or button, as it is commonly called, and the commercial quality of the fruits.

PLAN OF THE WORK.

Owing to the danger of injury to the lemons in the curing rooms and consequent heavy loss to the owners from improper conditions of temperature and humidity, it was decided to study the condition of relative humidity and its control in empty rooms and with small samples of fruit before attempting the control of humidity in rooms filled with lemons.

In the first place, a study was made of the use of ventilation in controlling the condition of humidity in the curing rooms. At the time these studies were begun, in July, 1914, and during the following four or five months, the relative humidity of the atmosphere at the place where these observations were made was normally very low. The humidity of the air in the warmest part of the day, usually about 2 o'clock in the afternoon, sometimes dropped to less than 10 per cent. The coolest part of the day during this same season was usually about sunrise, and at that time the relative humidity was frequently about 90 per cent and often reached 100 per cent. It was decided to

attempt to hold the relative humidity of several curing rooms at about the following conditions, viz, 70 per cent, 75 per cent, 80 per cent, 85 per cent, 90 per cent, and 95 per cent.

The rooms were kept tightly closed during the day and opened at night, when the conditions of the outside atmosphere were such as to make ventilation advisable, in order to assist in maintaining the inside condition of humidity at the desired point. Owing to the extreme fluctuation of the conditions of relative humidity in the outside atmosphere during the day and night and from day to day, ventilation alone was found to be impracticable as a means for maintaining a uniform condition of humidity in the curing rooms. It was found that excessive humidity in the rooms could be quickly reduced by opening the ventilators during the day, when the dew point of the outside air was much lower than that of the air inside the rooms. The real difficulty was found to be that of increasing the humidity in the curing rooms when it dropped below the condition desired.

METHODS TRIED FOR INCREASING THE RELATIVE HUMIDITY.

Several methods were tried for adding to the humidity in the curing rooms. The ground under one of the curing rooms was sprinkled with water. This method proved objectionable from the fact that by its use molds which were injurious to the fruit began to develop. Then a small perforated water pipe was arranged along the sides of one room, near the top, with a valve to regulate the spray of water from the pipes. This method was found to be inadequate. Later, sacks of coarse, heavy cloth were suspended from these pipes and the spray of water was allowed to fall on them. This method was also found to be ineffective.

A commercial humidifier used in tobacco warehouses was tried in one of the rooms. This machine consists in part of a rapidly revolving fan which throws a fine spray of water into the room. For the conditions in the lemon curing room this apparatus was found to be impracticable and was finally discarded. Other somewhat similar machines manufactured for the same purpose were used and found to be of little or no value for this work.

About this time the writer conceived the idea of increasing the humidity of the curing rooms when necessary by the evaporation of water from saturated cloths. Several ways of doing this were tried. The first apparatus consisted of a shallow, galvanized-steel pan, 2 feet wide, 3 feet long, and 6 inches deep. Into this pan was set a series of wooden frames, about 3 feet long and 1 foot high, spaced about 2 inches apart. During several tests they were covered with cotton and other absorptive cloths. The pan was nearly filled with

water, and in this condition the water was drawn into the cloths by capillarity almost to the top of the frames. Over the frames was placed a galvanized-steel cover, or hood, open at one end and so arranged at the other end as to inclose a 16-inch electric fan. The current of air from the fan was directed between and over the saturated cloths. In this way the water was evaporated and given off to the air in the room, increasing the relative humidity more efficiently and safely than by any method previously tried. However, it was soon found that the upper part of the cloths soon became dry under the influence of the air current from the fan, and in an hour or so the effectiveness of the apparatus became greatly diminished.

An attempt was then made to find a cloth more absorptive than the kinds first used. Many materials were tried, with the result that it was decided to use Russian crash, a very coarse linen cloth that is used for making towels and for decorative purposes.

With the use of the Russian crash cloths the efficiency of the humidifier was improved, but it was still imperfect under very dry atmospheric conditions. Various expedients were tried to increase still further the evaporation of the water in the pan, such as by the addition of filter paper, sponges, and other quickly absorptive materials.

THE INVENTION OF THE HUMIDIFIER.

While working on this phase of the problem, the writer constructed a machine with two water pans, an upper and a lower one, with strips of cloth extending through slots in the bottom of the upper pan to the lower pan. It was thought that in this machine it would be possible to control the flow of water from the upper pan to the cloths through the slots by pressing the slots together by means of thumbscrews. This method was found to be impracticable. It was in this work that the idea occurred of raising the sides of the slots several inches, so that they protruded above the water in the top pan. The cloths were drawn up through the raised slots and the edges were allowed to drop into the water to the bottom of the pan.

Under these conditions, the water in the pan was raised on the cloths by capillarity to the top of the raised slots, where it dropped down through the suspended cloths by gravity and capillarity combined. This arrangement proved to be successful in every respect and met the requirements for use in lemon curing rooms very satisfactorily.

It was found that the rate of flow of water from the upper pan through the cloths to the lower pan could be regulated to a nicety by varying the height of the raised slots, thereby changing the length of the cloth through which the water is drawn by capillarity.

Naturally, the higher the raised slot extended above the water, the slower was the passage of water to the lower pan.

In this work it is desirable to keep the cloths saturated during the operation of the machine, but with little or no excess of water dripping into the lower pan. As finally constructed, after many tests to determine the best arrangement, it was found that raising the slots 4 inches above the bottom of the pan keeps the cloths fully saturated under the conditions in which this machine is used. Another method of controlling the flow of water through the cloths is to vary the quantity of water in the upper pan, filling up the pan so that the water nearly reaches the tops of the raised slots in order to increase the rate of the flow or drawing off some of the water in order to retard its flow.

If it is desirable to stop the absorption of the water by the cloths at any time, this can be done easily by lifting the ends of the cloths out of the water in the upper pan. If the flow of water through the cloths is such as to collect in the lower pan, this excess can be drawn off and returned to the upper pan. Under conditions of very low humidity, when evaporation from the cloths is very rapid, it may be found advisable to maintain some water in the lower pan, as well as in the upper one, in order to keep the cloths fully saturated.

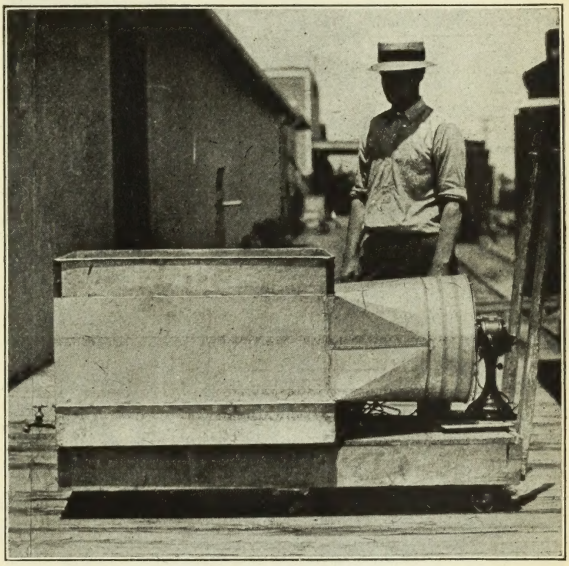

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FIG. 1.—Side view of the humidifier, showing its arrangement on a truck and the spigot for drawing off excessive water in the lower pan.

The operation of this humidifier washes all of the air in the room and increases the humidity uniformly, a very important factor in lemon curing rooms. Another fact of great importance is that under conditions of low humidity the humidifier acts rapidly, while under conditions of high humidity it works slowly. One advantage of this condition is that it reduces the danger of raising the humidity of the curing room to a point which would be unfavorable for lemon curing. On an average the humidifier will raise the humidity in the rooms de-

scribed about 10 per cent per hour in the range from 70 to 90 per cent of relative humidity. In a condition below 50 per cent of relative humidity the humidifier acts more quickly, while at about 90 per cent it works very slowly; in fact, it has been impossible in these experiments to raise the humidity in the curing rooms during very dry days much above 95 per cent with this apparatus.

CONSTRUCTION OF THE HUMIDIFIER.

The illustrations of the humidifier (figs. 1 and 2) show its general arrangement and its position on a truck, whereby it can be moved from place to place when needed. The detailed structure of the humidifier is shown in figures 3, 4, 5, 6, and 7. The upper pan (1) is 36 inches long, 24 inches wide, and 6 inches deep. The lower pan (2) is of the same dimensions. The side (4) of the cloth chamber (3), which is open at both ends, is 36 inches long and 20 inches high, connecting the upper and lower pans. The raised slots (5) are 4 inches high and extend to within half an inch of either end of the upper pan, so that they are held firmly in position. The upper ends of the raised slots are spread slightly, so as to allow the easy passage of the strips of cloth (6). The pans, sides, and other metal parts are made of galvanized steel of medium weight. The corners of the cloth chamber are strengthened with angle iron. The upper edges of the strips of Russian crash are drawn through the raised slots and allowed to drop down into the water in the upper pan, as shown in figure 7 at 7. The bottom edges of the cloths are bound with strips of sheet metal (8), so as to hold them in place. These bound edges of the cloth strips are held in the lower pan by means of spring clips or clamps (9) which are soldered to the bottom of the lower pan. The strips of cloth are 35 inches wide, so as to fit the raised slots,

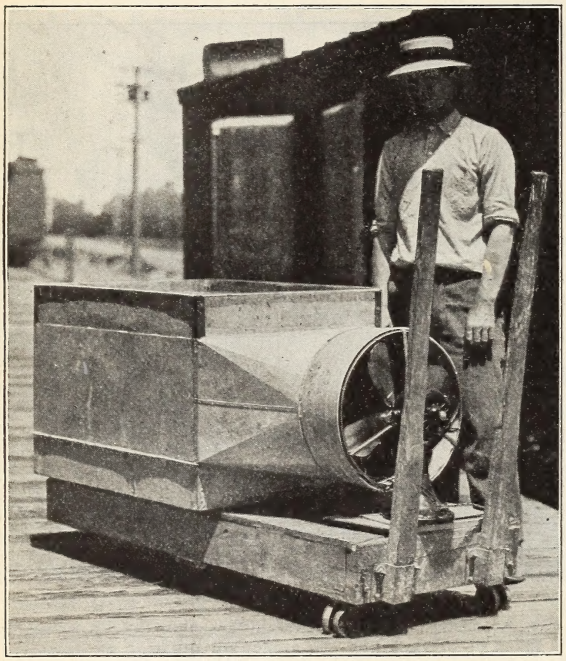

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FIG. 2.—Rear view of the humidifier, showing the arrangement of the electric fan in the hood.

and 36 inches long, so as to extend from the lower pan through the raised slots and drop over into the water in the upper pan.

In machines constructed after the accompanying illustrations were prepared it was found desirable to have the forward edges of the hood (10) fit inside the opening made by the top and bottom pans and the inner edge of the angle iron in the corners of the cloth chamber. The hood is drawn out to a circle so as to fit the circumference of the blades of the electric fan (11), which is 16 inches in diameter. The humidifier is placed on a truck (12), supported on wheels (13) so arranged that it can be easily moved in any direction by means of the handle (14). Supports (15) are placed under the humidifier and fan to raise them sufficiently to permit a pail to be easily placed and removed from under the spigot (16).

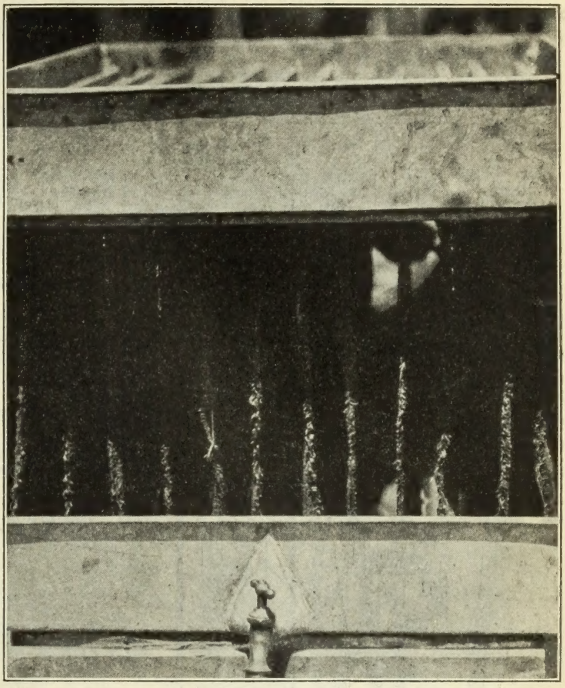

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FIG. 3.—Front view of the humidifier, showing the arrangement of the absorptive cloths in the cloth chamber.

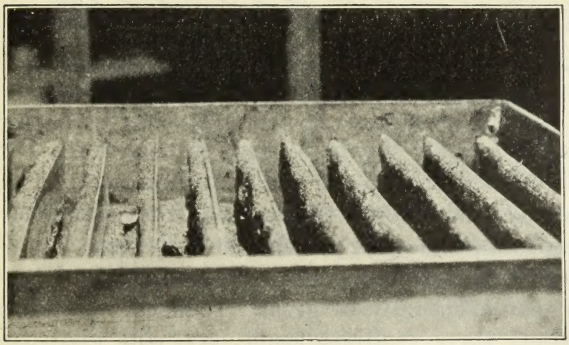

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FIG. 4.—Top view of the upper pan, showing the arrangement of the raised slots and the absorptive cloths. The cloths drop from the raised slots to the bottom of the pan.

OPERATION OF THE HUMIDIFIER.

Space must be left in the curing rooms so that the humidifier can be quickly placed in position for use and easily taken out.

The upper pan should be filled to the proper point with water, care being taken to see that the edges of the cloths are entirely submerged. The fan should then be started.

Frequent readings of the humidity in the rooms should be made, once every hour in the beginning, by means of the sling psychrometer. A record should be kept of these readings from the beginning to the end of the curing process. A convenient form for recording these data is as follows:

Humidity record of the curing room.

Date.	Time.	Air temperature.	Psychrometer readings.		Relative humidity.	Dew point.	Outside air.		
			Dry bulb.	Wet bulb.			Temperature.	Humidity.	Dew point.

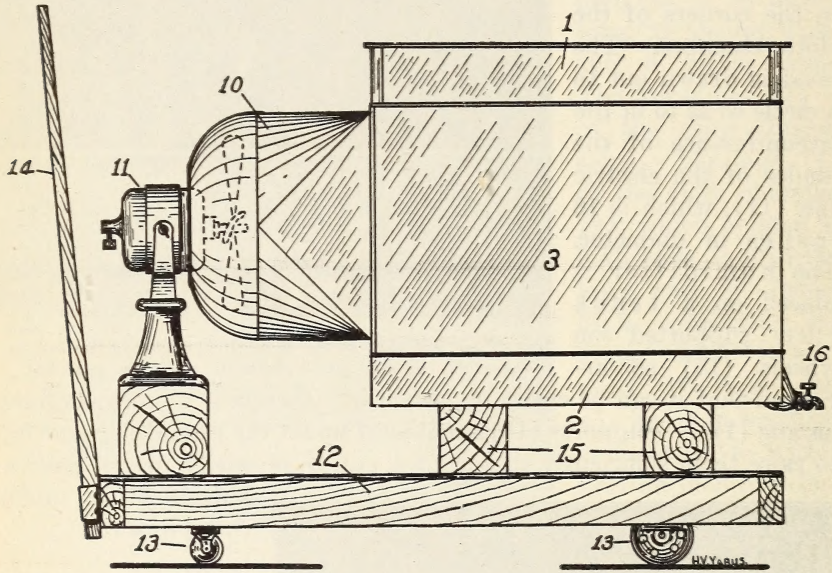

FIG. 5.—Side view of the humidifier, showing details of construction.

A covered jar of distilled water should be kept in each room for moistening the cloth on the wet bulb of the sling psychrometer. The air temperature of the rooms should be determined from standardized thermometers hung in a permanent position in each room.

In practice it has been found that the number of humidity determinations in the rooms can eventually be greatly reduced. Usually, during ordinary weather, three readings each day will give the necessary information for use in handling the humidifier. With fluctuating weather conditions the readings will of necessity be made more often. It is very desirable to make at least one, preferably more than one, daily determination of the air conditions outside

the curing rooms, in order to handle the humidifier and the ventilation of the curing rooms intelligently.

For rooms of the kind and size and under the conditions described in this paper one humidifier will generally be sufficient for use in five rooms. With better insulation for the rooms fewer humidifiers will be needed, and where the insulation is not so good or where temperature fluctuations are greater than those where these rooms are located, more humidifiers will be needed. The cost of the humidifier need not exceed $25, in addition to the electric fan. The cost of operation will depend on the cost of running the fan. The depreciation in the value of the apparatus is insignificant.

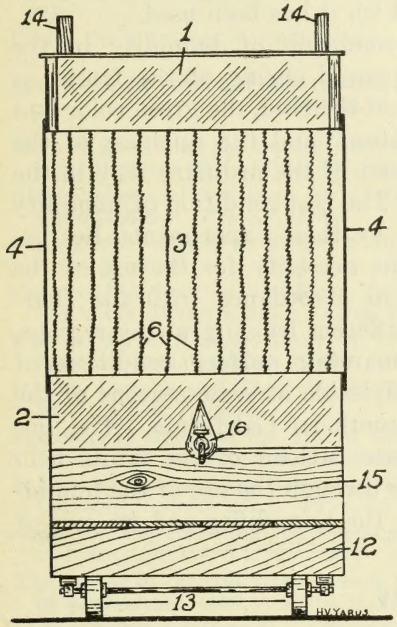

FIG. 6.—End view of the humidifier.

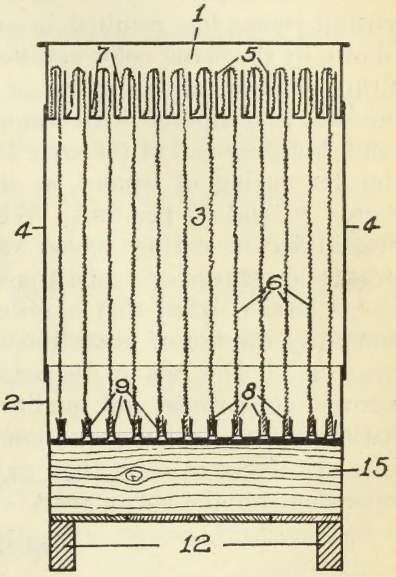

FIG. 7.—Cross section of the humidifier.

If impure water is used in the humidifier it will be found necessary to wash the absorptive cloths occasionally. When the humidifiers are not in use the cloths should be allowed to dry out thoroughly.

OTHER USES OF THE HUMIDIFIER.

The successful use of the humidifier described in this paper in improving the humidity of private homes and other living rooms has been demonstrated. In this case, much smaller humidifiers can be used. The noise caused by the vibrations of the electric fan in contact with the humidifier hood can be largely eliminated by inserting a strip of rubber at this point.

The use of the humidifier in dry or desert sections, in restaurants, offices, and living rooms not only increases the humidity in these rooms but also lowers their temperature, both of which conditions

are very desirable during excessively hot weather. In view of the fact that the only attention needed other than that given the ordinary electric fan is to keep the upper pan filled with water, the operation of this humidifier is simple and practicable.

RESULTS.

The use of the humidifier described in this bulletin in lemon curing rooms for two seasons has demonstrated the possibility of maintaining a uniform condition of relative humidity in such rooms. The action of the humidifier is entirely safe, and there has been no injury to the fruit in the curing rooms in which it has been used.

The maintenance of a uniform condition of humidity in the curing rooms has resulted in an improved curing of the fruits, as shown by the better color and texture of the rind, the green color and firm condition of the calyx, or "button," and the juiciness of the lemons, as compared with lemons cured in the ordinary way in the same building and at the same time. The best condition of humidity for the curing of lemons, as shown by these experiments, lies between 80 and 90 per cent. While the necessity for the use of the humidifier in curing rooms varies in accordance with the characteristic atmospheric conditions of different lemon-growing regions, it can be said safely that in order to maintain uniform conditions of humidity the use of humidifiers is advisable at some seasons of the year in all the lemon districts of southern California. The improved appearance and quality of one carload of the fruits held under uniform conditions of humidity through the use of the humidifier are likely to more than pay for the humidifier and its cost of operation for the entire year.

SUMMARY.

A humidifier for use in maintaining conditions of uniform humidity in lemon curing rooms was invented by the writer in 1914.

This humidifier was the outcome of a series of experiments for the purpose of controlling the conditions of humidity in lemon curing rooms.

It has been satisfactorily and successfully used for two seasons for the purpose for which it was built, and also for improving the air conditions in living rooms in private houses and elsewhere in California.

The arrangement and structure of the humidifier are described and illustrated in this paper. It need not cost, aside from the electric fan, more than $25.

The best condition of relative humidity for curing lemons, as determined by these experiments, lies between 80 and 90 per cent.

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